Working with Stakeholders: Engaging Sectors to Influence the Future of EPIC and UFS

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EXECUTIVE SUMMARY

Amidst the challenges posed by extreme weather events and the progression of climate change, advancing weather forecasts and prediction are pivotal to enable impactful societal outcomes. The rising frequency of, and challenge to predict, extreme weather events calls for cross-sector and multi-disciplinary partnerships, which involve integrating knowledge and feedback from the public, private, and academic sectors. For this reason, the National Oceanic and Atmospheric Administration (NOAA) and its partners established the Unified Forecast System (UFS) in 2017, a comprehensive, coupled, community modeling system. In 2018, Congress called upon NOAA to establish the Earth Prediction Innovation Center (EPIC) program to improve community access to the UFS and enable more rapid innovations into operations. Enabled by EPIC, the external community can contribute to the UFS to accelerate advances in the Nation's operational forecast modeling systems. Moreover, integrating stakeholder feedback and engagement can help align user, developer, and operational needs to the technological aspects of EPIC and UFS as highlighted in previous work completed by Michaud, Eosco, and Dubots (2022). Following the 2022 Unifying Innovations in Forecasting Capabilities Workshop (hereby UIFCW or "workshop") we identify a need to define community as it relates to a cross-sector involvement to improve weather modeling (Michaud & Eosco, 2022), elaborate on community membership, clarify governance structures, evaluate action plans, and generate ideas for a path forward.

Community engagement best practices generated from a literature review of social science research were applied to feedback collected during the 2022 UIFCW hosted by the EPIC, UFS, and UFS Research to Operations (R2O) Project in College Park, Maryland and online. The methods used to collect and analyze stakeholder feedback include the online messaging forum, Slack, workshop events, question and answer sessions, comprehensive notes, agendas, and a post-workshop survey. At the workshop sessions questions were developed for moderators to provide direction during discussion gaps. These questions sought to address community engagement elements identified in the literature review as well as the challenges, outcomes, and goals stakeholders presented through their research, presentations, and conversations. Community engagement best practices themes included co-production, community values and dialogue, governance, and the community environment.

Following the UIFCW, we qualitatively analyzed the data collected during the workshop based on the community engagement best practices. Findings highlight the motivation amongst stakeholders to foster cross-sector collaboration and innovation as well as utilize open-source code. However, with these advantages come various

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challenges faced by users and developers including limited user support, coding and computing barriers, low level of collaborator interaction, and eligibility concerns related to who is in, or out of, the community. The frameworks designed by EPIC and the UFS of a modeling platform and code releases have the capacity to support co-innovation, but are currently impeded by structural limitations related to workflow and documentation as well as the lack of diverse presence from an array of stakeholders, including but not limited to researchers and developers, academic users, and members of the private sector, at events like the UIFCW.

Given these findings, ideas for a path forward include building a cohesive and collaborative research and application environment through a variety of infrastructure and engagement techniques. Specifically, action items generated at the UIFCW include building greater outreach through a mailing list and social media, creating common communication platforms for collaboration and support, designing an inclusive and accountable governance system, and supporting capacity-building for all existing and future participants.

Other ideas for a path forward could include focusing on the allocation of funding resources, support systems, training, designing communication platforms for stakeholders ranging from code developers to researchers to forecasters, and clarifying a governance structure that emphasizes entry, support, engagement, and application. Fostering co-production and capacity-building among stakeholders can include aligning project goals to a stakeholder's context, incorporating a diverse range of disciplines in the community of UFS, developing incentives for participation and long-term engagement, and fostering knowledge sharing.

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INTRODUCTION

Background

Weather actively influences the condition and health of societies and economies throughout the United States and the world. Understanding weather dynamics serves a vital function in analyzing and responding to how these societies experience weather events. Amidst the rising challenges to predict and respond to extreme weather events such as Hurricane Sandy in 2012, the historic 2021 and 2022 Western wildfire season, and extreme Southeastern floods in Tennessee (2021) and Kentucky (2022), committing to the advancement of weather forecasting and prediction is pivotal.

In order to meet this challenge, NOAA created EPIC to accelerate advances in our Nation's operational forecast modeling systems and reduce the technological barriers of entry for external participants to access UFS code. In response to public concerns comparing the U.S. weather model performance to the European models, identifying opportunities to improve the quality and functionality of numerical weather prediction systems is a vital function of EPIC. As such, fostering the growth of cross-sector partnerships in developing, tailoring, and advancing weather models provides the expertise and resources necessary to support the UFS, a community-based system and the source code for NOAA's operational forecasting.

In an effort to identify successes and challenges related to NOAA's endeavor to build a community modeling system, EPIC hosted its first community engagement workshop in the summer of 2019 (NOAA, 2019). In an internal analysis and report completed in the summer of 2021, it was shown that community membership plays a significant role in shaping one's contributions and motivations for participating in building the UFS (Michaud, Eosco, & Dubots, 2021). Additionally, it was noted that continuously improving and clarifying the communication outlets and model integration processes within the UFS may yield greater cross-sector dialogue and collaboration (Michaud, Eosco, & Dubots, 2021).

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PAST FINDINGS AND RECOMMENDATIONS

Understanding the evolution of community modeling as it relates to engagement is an important step in approaching the analysis of the workshop held in the summer of 2022. After an analysis of the definition of community and community modeling in the summer of 2021 (Michaud, Eosco & Dubots, 2021), NOAA deepened its commitment of cross-sector collaboration through EPIC by means of funding opportunities and fostering modeling research. Moreover, research by Dr. Gina Eosco and Michael Michaud highlights the importance of integrating incentives, embracing the capacity of people, and diversifying knowledge transfer (Michaud & Eosco, 2022).

The previous workshop report emphasized the need for EPIC to expand its focus on community as it relates to facilitating the sharing of knowledge across entities (NOAA, 2019). As various sectors participate in UFS's modeling community, identifying the differences in expectations and motivations among the participating groups is another vital facet of improving numerical weather forecasting and prediction in the U.S. under the UFS framework. Moreover, identifying these elements also constitutes strengthening community membership and active dialogue whereby differences in coding structures and timeframes can become more cohesive. Tailoring EPIC's actions in the aforementioned areas can help to address challenges presented by past workshop attendees including entry barriers, modeling integration, overcoming technical and operational challenges, transparency, and decision-making capacity (Michaud & Eosco, 2021).

Social science research served as a lens for the report on the Summer 2022 UIFCW to identify the elements of communication, co-production, and community values within the UFS modeling community. Internalizing these findings will help the UFS and EPIC's mission in unifying research goals across members of the modeling community while at large, contributing to NOAA's aim to establish a Weather-Ready Nation.

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FOUNDATIONAL METHODOLOGY

The analysis framework consists of two components. The first component utilizes findings from community engagement best practices research as a method for a qualitative assessment of data collected from the workshop. The second component includes an assessment of community recommendations and the evolution of these recommendations as they relate to EPIC's initiatives and Strategic Plan objectives (EPIC Strategic Plan, 2021).

Methodology

The purpose of this study was to perform a qualitative analysis on community engagement best practices as they relate to EPIC's initiatives to build a modeling community under the UFS. In order to observe and analyze the presence and/or absence of community engagement elements within the dialogue between EPIC and community modelers, we designed three feedback avenues: Slack moderator questions, thematic notes, and post-workshop survey questions.

The first avenue included the online chat forum, Slack, as a form of active engagement with in-person and virtual workshop attendees. Questions were designed for moderators to address community engagement elements identified in a literature review of social science research as well as the challenges, outcomes, and goals stakeholders presented through their research and conversations. Specifically, the lens for these questions is seen in Figure 1 and the questions listed in Appendix 1. Tailoring the framework of these questions to the session's content helped to produce outcome-based discussions, sustain stakeholder engagement, and understand stakeholder relationships with EPIC and the UFS.

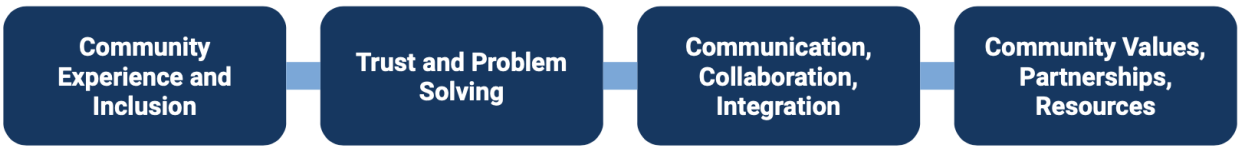

Figure. 1. Community engagement question framework. Moderator questions posed within the online chat forum, Slack, focused on attendees' experience with EPIC and the UFS relating to community experience and inclusion, trust and problem solving, communication, collaboration, and integration, and community values, partnerships, and resources.

Second, comprehensive outlines for notes were created to structure summaries, reflections, and stakeholder input from each of the workshop sessions. The outlines,

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provided to volunteer notetakers, primarily focused on identifying community engagement themes and practices, synthesizing stakeholder feedback, noting stakeholder discussion points, and summarizing content of presentations. These notes were foundational to the development of this report, shaping ideas for a path forward for EPIC based on stakeholder perspectives and input.

Lastly, working alongside Leah Dubots, Jen Vogt, Michael Michaud, and Jonathon Mote, a post-workshop survey was designed to collect feedback from participants. The survey followed all regulations within the Paperwork Reduction Act of 1995 approved with the Office of Management and Budget (OMB) Control Number 0690-0030. The survey focused on two main elements: collecting workshop feedback and understanding individual experiences related to the UFS. Open-ended questions were developed to understand the nature and condition of one's relationship with the UFS. The open-ended questions sought to identify three areas: one's role in the ongoing development of the UFS, one's experience working with the UFS, and the resources and barriers surrounding one's collaboration with and among users.

Stakeholder perspectives and suggestions should not be limited by the findings presented in this report; additional data is available for analysis in the Slack channels, thematic notes, and survey responses. For the purposes of this report, a synthesized analysis was performed on a handful of common themes identified between sessions and attendees as well as potential ideas for a path forward. Continued analysis on this front is strongly encouraged as well as continued use of collected stakeholder feedback from the UIFCW.

Foundation and Lens

In order to understand stakeholder perspectives, goals of EPIC and the UFS, and craft ideas for the EPIC Team, preliminary research was completed to identify community engagement best practices and their applications as they relate to building community partnerships and unified value thread. By way of employing grounded theory, we entered the workshop with the intent to identify thematic intersections and analyze stakeholder feedback and presentation materials. Grounded theory specifically constitutes assessing data after it has been collected in an effort to identify and investigate relationships between themes and data sources (Charmaz, 2015, p. 402).

Using scientific databases, we analyzed a series of peer-reviewed journal articles focusing on technical and behavioral sciences. From this research we identified five community engagement tenets which serve as key analysis themes (Figure 2). These

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tenets also represent a preliminary structure for analyzing whether or not the community experience amongst stakeholders of the UFS aligns with meaningful participation and collaboration.

Figure. 2. Community engagement tenets developed from peer-reviewed journal articles which focused on technical and behavioral sciences. These include: community dialogue, community values, conflict resolution and integration, governance and decision-making, and co-production.

The five community engagement best practices provide a basis for the analysis of the presence, absence, and need for improvement of community engagement elements within EPIC and the UFS. Using these elements helps to identify how a community seeking innovation and collaboration across various sectors can thrive and helps to inform decision-makers of the conditions necessary to foster active engagement and problem-solving. Other elements, such as integration and governance, work to provide suggestions for capacity-building strategies that encourage the inclusion of diverse perspectives and knowledge transfer. Co-production serves as a common thread between each of these elements, fostering the growth of an agile and cohesive structure where advancements to weather forecasting and prediction can be made.

Community Engagement Best Practices

1. ***Community Dialogue***
   - ***a.*** Small-group dialogue to facilitate larger conversations (Reimers, 2016, p. 445)
   - ***b.*** Regular training, common language, sharing responsibilities (Hanisko, 2022)

2. ***Community Values***
   - ***a.*** Tailored solutions and integration given contexts (Yet et al., 2022, p. 207)
   - ***b.*** Distance and goal alignment with mentors, timeline of progress and trajectories (Kaur et al., 2020, p. 13; Dyer et al., 2014, p. 140)

3. ***Conflict Resolution and Integration***
   - ***a.*** Trust and cooperation (Reimers, 2016, pp. 443-444)
   - ***b.*** Reducing entry barriers, providing training and support systems for

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new developers (Kaur et al., 2020, pp. 12-17)

4. ***Governance and Decision-Making***
   - ***a.*** Accessible structure, consent from all stakeholders (Colvin et al., 2016, pp. 484-490)
   - ***b.*** Peer-based power structure, consistent input (Yet et al., 2022, pp. 190-207)

5. ***Co-Production***
   - ***a.*** Mutual reinforcement, broad participation, plural perspectives (Boyle et al., 2022, p. 3)
   - ***b.*** Reciprocity and adaptability in sharing knowledge and overcoming challenges (Boyle et al., 2022, p. 3)

Adjusting the Frame, a 2022 Vision

Three years after the first EPIC workshop, the EPIC, UFS, and UFS R2O Project Teams collaborated to plan the UIFCW to address past recommendations for advancing community modeling initiatives. This UIFCW Community Workshop Report seeks to represent community input, feedback, and ideas for a path forward for community modeling as it relates to implementing EPIC and UFS to build a Weather-Ready Nation. By utilizing social science methodologies and past research and recommendations on EPIC, this report can be used to inform UFS's modeling advancements and community partnership goals.

Setting the vision for a unified, collaborative future requires a reflection of the goals set before those contributing to the UFS and those considering future partnerships. At the start of the UIFCW, NOAA strongly stated its commitment to addressing various forms of environmental challenges including drought, fire, floods, and hurricanes as well as the socio-economic vulnerabilities resulting from these challenges. Specifically, NOAA and UFS leadership discussed the importance of fostering community partnerships as relationships are integral to the advancements of research and operations.

Building cross-sector relationships is no small feat and there are various elements necessary to the success and longevity of the UFS. Enabling innovation from the private, public, and academic sectors requires diversity, reciprocity, adaptability, transparency, and clarity. As noted by modeling leadership, these conditions must exist within all aspects of building and improving the UFS, including model development, education and outreach, governance, and the creation of user support systems.

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Moreover, in order to foster long-term engagement with stakeholders, the aforementioned qualities must exist in the forms of ensuring equity and inclusion, the perspectives and tools from different model disciplines, and incorporating the voices of the next generation.

In this report, community engagement best practices generated from a literature review of previous social science research were applied to the context of EPIC, UFS, and the motivation to build a modeling community under the UFS. In addition, stakeholder feedback collected from Slack, workshop events, Q&A sessions, and a post-workshop survey were synthesized. By way of collecting and analyzing feedback, various community engagement elements were evaluated for their presence, absence, and need for improvement. Lastly, ideas for a path forward were generated after analyzing the aforementioned subject areas in an effort to guide the UFS and EPIC's goals for the future.

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ANALYSIS

Cross-Section: Community and Engagement

The discussions held at the UIFCW generated a deep evaluation of the meaning behind community as it relates to one's connection to the UFS, including necessary resources, barriers, and goals. Through the lens of the workshop's discussions, the elements above (i.e., community dialogue, community values, conflict resolution and dialogue, governance and decision-making, and co-production) have gained a nuanced understanding, particularly as they relate to stakeholder perspectives and aspirations. Throughout panelist sessions and subsequent Q&A discussions, various questions were raised by workshop attendees, drawing into focus the need to reevaluate the definition of community, members of the community, governance structures, and commitment to goals set forth at meetings such as the UIFCW.

Based on our analysis, findings from the UIFCW can be organized into the following thematic categories: community, organizational structure, stakeholders, governance, and purpose (Figure 3). Understanding workshop discussion and participant feedback through these categories helps to contextualize elements such as co-production and community values.

Figure. 3. UIFCW findings outline. Based on our analysis, findings from the UIFCW can be organized into the following thematic categories: community, organizational structure, stakeholders, governance, and purpose.

Within this analysis, the word "community" is used loosely. As demonstrated in past work by Michael Michaud and Dr. Gina Eosco, the term community is yet to be firmly defined in the context of the UFS. Thus, this report supports the need to define the term community as it relates to cross-sector, cross-disciplinary involvement to improve weather modeling (Michaud & Eosco, 2022). While workshop attendees expressed the importance of developing and sustaining a co-developed, interdisciplinary, and communicating community, at this time, a "community" under the UFS requires evaluation and improvement to better foster these elements.

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EPIC and UFS

Considering that the UFS and EPIC serve as foundations for the advancement and organization of community modeling for the weather enterprise, clarifying and confirming their respective functions is essential.

UIFCW participants achieved consensus surrounding the perspective that the UFS is a broad modeling infrastructure capable of fostering innovation across stakeholders. The UFS' vision to bridge community expertise and experience was a celebrated element of conversation at the UIFCW. From the perspective of the academic sector, representatives felt aligned with EPIC and UFS' initiatives to foster community modeling in an effort to expand research. Moreover, open source code collaboration offers a multitude of benefits including its ability to foster cross-sector partnerships and academic inclusion. However, due to the UFS' emphasis on partnerships between domestic United States entities, academic and international attendees felt the scope of participation within the UFS was limited. Fostering international inclusion in the development and advancement of modeling research was a frequent suggestion from attendees of the academic arena.

Another element questioned by workshop attendees was the idea of "community." The word "community," as it relates to membership with the UFS, was unclear specifically relating to its level of capacity-building and decision-making capability. Participants from the academic, public and private sectors felt funding allocation was a driving factor to feel included in the work occurring in the UFS. As a result, a lack of funding may result in the feeling of exclusion. Common questions asked during the Q&A sessions of the workshop are included in the following series:

1. What is community?
2. Who makes up the community?
3. What are the roles and responsibilities of EPIC and UFS respectively?
4. How are models, disciplines, and perspectives involved in governance?
5. What is the role of community engagement in the UFS mission?

These questions suggest the organizational structure of "community" as used by the UFS does not adequately sustain engagement due to ambiguity surrounding inclusion and purpose. The role of EPIC was also discussed. Stakeholders recognized EPIC as a support infrastructure, however, participants suggested that greater access points, compute access, clarity on eligibility requirements and releases, and funding opportunities supplied by EPIC would clarify the entity's role in relation to the UFS. Supporting the growth of student opportunities including fellowships and clarification of

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code releases would better serve community members approaching the UFS with entry questions or research needs.

A last topic of discussion surrounding the roles and responsibilities of EPIC and the UFS includes the characteristics of community modeling. After observing the dialogue at the UIFCW and the online comments during Q&A sessions, stakeholders were hopeful about engaging each other on the intersection between technical and social elements of community modeling in the future. Crafting discussions around knowledge transfer rather than solely on the developmental aspects of independent research projects was a common theme across stakeholders. The need for social science research and applications in the creation of a modeling community, research development, and research applications was addressed by various panelists. This emphasis suggests a call-to-action for social scientists to share their expertise in the research-to-operations funnel of the UFS.

Participation and Community Environment

Co-Production

In an effort to elaborate on the meaning of community and how it relates to the application of modeling, we have chosen co-production as a facilitating third-element in this analysis. Based on our literature review, co-production[1] can be understood as an environment built on mutual reinforcement, broad participation, and plural perspectives. Additionally, co-production entails reciprocity and adaptability in sharing knowledge and overcoming challenges (Boyle et al., 2022, p. 3).

Considering capacity building as a function of co-production aids in clarifying the challenges faced by UFS members and prospective partners. In the context of the UFS and EPIC, co-production would constitute cross-sector partnerships that work collectively through resources and communication platforms to achieve shared goals. Collaborating in this space would facilitate open dialogue, the sharing of goals and challenges, and problem-solving together. During a discussion on the roles and responsibilities within the UFS, participants identified a variety of capacity concerns to achieve effective co-production. These concerns can be broken down into four main categories: barriers to participation within existing governance structures, resource constraints, the role of individual contributors, and risk aversion.

The integration of elements of co-production within the community includes gaps. Throughout the workshop stakeholders noted their concern about the imbalance

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of resources across contributing groups, specifically related to the availability of funds for more innovative work. A barrier seems to be present where an organization's funding or lack thereof may impede their engagement with the UFS and EPIC. As a result of these funding limitations, the scale and accessibility of research varies across stakeholders, creating an imbalanced and non-representative governance structure. Capacity at the individual and organizational levels are not adequately supported by mechanisms like funding, weakening one's feeling of connection to the UFS.

While the open source nature of the UFS was widely celebrated by participants, stakeholders noted it can be challenging to experience rapid changes in code. To help adjust to these updates, participants suggested more training on the code and improving the "points of entry." Updates like these could significantly foster a greater sense of cohesion and co-production. Building a community where innovation is attainable and practical for every stakeholder can propel active dialogue and engagement, resulting in more innovations. Managing the code complexity and training resources for students can also help incentivize participation and development. As a result, greater participation from partners at the undergraduate to mid-career level can be achievable.

Co-production as a form of collaborative and innovative engagement also connects to capacity-building. As mentioned previously, increasing funding opportunities for existing and future collaborators would play a significant role in equipping participants with the resources necessary to effectively communicate and co-develop. The academic sector also noted the importance of supplying help utilizing High-Performance Computing (HPC) under EPIC to ask questions and receive feedback. This feedback suggests capacity-building is a function of resource allocation and relationship-building.

Building a fully-coupled Earth System Model strongly relies on diverse participation. Based on the post-workshop survey, stakeholder[1] representation was predominantly from the government[1] sector. At the UIFCW, a lack of prominent stakeholder participation from the academic and private sectors may have limited the scope and scale of discussions surrounding model integration and participatory strategies. Stakeholders also noted that a larger emphasis should be placed on the dialogue between developers, users, and forecasters. The academic and government sector representatives suggested the UFS may benefit from supporting lower readiness-level research as well as the experience of students from interdisciplinary fields. Facilitating both efforts could contribute to a more thorough and cohesive Earth System Model where innovation is embraced from various levels, rather than serving as

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an exclusive platform. Fostering co-production throughout this research-to-application chain could better support UFS' mission to foster interdisciplinary research and applications, advancing innovation and the use of innovation from a variety of fronts.

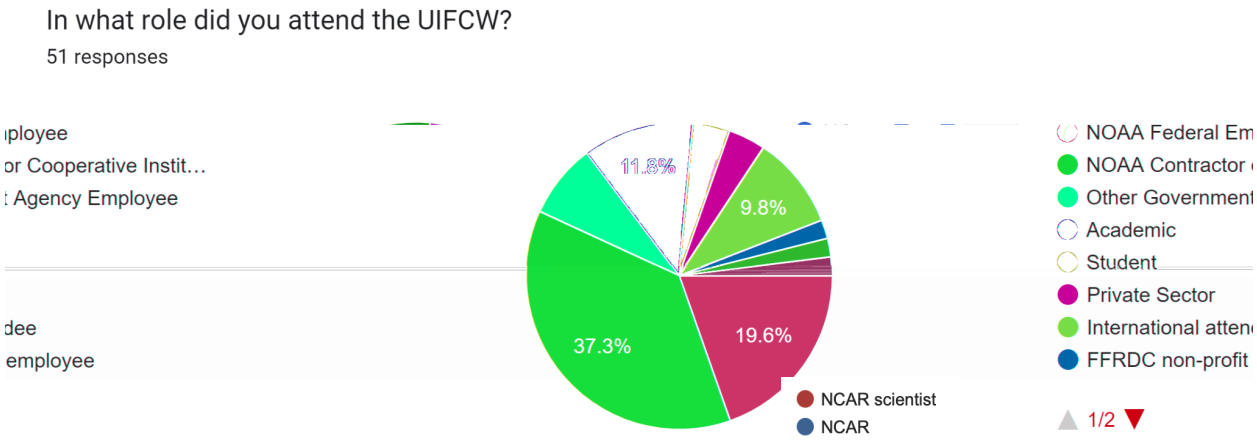

Figure 4. The Post-workshop survey (Appendix 1) showed a variety of participation across stakeholder groups, with a high Federal Government participation rate.

After considering responses from the post-workshop survey, co-production (i.e., collaboration between researchers and developers) as it relates to one's ongoing development of the UFS is apparent. Attendees expressed interest in offering ideas, reporting bugs, and contributing code and documentation. Elements such as continued development of physics schemes, code testing, and data assimilation efforts are supported by a growing spark in interdisciplinary project ideas and improvement. Such responses from the post-workshop survey suggest co-production is accepted and anticipated with stakeholders of differing interests and motivations to share knowledge.

Stakeholders presented various challenges and suggestions as related to co-production and building a community environment within the UFS. Survey responses emphasized that barriers to entry and instruction about how to use the UFS are limited. Engaging with others as well as managing projects can benefit from revision in terms of portability, training, and cross-sector dialogue. Moreover, participants noted that the functionality of the Joint Effort for Data assimilation Integration (JEDI), progress of building stacks for UFS applications, challenges with access to open-source code, workflow usability, and the lack of documentation makes it difficult to co-produce and integrate feedback. Expanding resources to the UFS community, such as training services and UFS user guides, as well as developing a common platform for library development and communication, may ease one's entry into the UFS. Providing tailored

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resources for specific users may also limit perceived barriers to entry for certain sectors or groups. Moreover, improving the access to code and creating a directory for information sources may help participants and their workflows.

Community Dialogue

Communication was questioned during the workshop by stakeholders in two primary perspectives: technical translation and group discussions. Throughout presentations from modelers and social scientists, communication as a facilitator of knowledge transfer and relationship building appeared to be an integral theme in both improving research and creating a unified community.

Community dialogue, from the lens of community engagement best practices research, can be understood as an active integration of common languages, shared responsibilities, and regular training (Hanisko, 2022). A community built on cooperation and cohesion helps to foster long-term engagement while emphasizing the importance of conversation facilitation (Reimers, 2016, p. 445).

Workshop participants reflected on the UFS as an integral environment for the advancement of NOAA's modeling capacity and organizational collaboration. Community dialogue in this context considers the facilitation of discussions between researchers, developers, users, forecasters, leadership members, and more. Active pathways to support these discussions as well as the structure of discussions including the emphasis on knowledge transfer and technical development is another contributing factor.

The value of communication did not go unnoticed, but rather, was seen as the catalyst for various technical improvements made to projects like the UFS R2O by way of fostering cross-sector innovation. While the current state of communication as recognized by the stakeholders consists of gaps, stakeholder feedback has produced a vast array of perspectives and ideas for the future. Specifically, attendees expressed their concern about cross-organizational coordination. Given the varying levels of code and model experience as well as project timelines, fostering knowledge sharing across sectors is a challenge. Moreover, discussions on failure versus success are not equally embraced. As mentioned previously, the idea of risk aversion due to a lack of funding or perspective on incompletion may limit knowledge transfer as it relates to dialogue between developers. Building community dialogue and community collaboration around the idea that unintended results from research are not failures was a common theme across panelists; this suggestion could help build confidence and participation

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from stakeholders while supporting an environment and dialogue around the equal sharing of successes and challenges. In other words, embracing raw innovation rather than an ideal end-product has the capacity to engage those with broader research interests.

Analyzing community organization and roles also supplements the tenet of community dialogue. Specifically, representatives from the academic sector, including student workforce and early career professionals, expressed the challenges they face with identifying project priorities. In this way, entering the UFS community as well as confirming a project plan for model development is not entirely clear, impacting one's feeling of connection to other developers and researchers. Additionally, barriers such as limited experience with particular code languages and training have created confusion for those within academia working on low readiness-level research. Discussions on the aforementioned topics suggest capacity building and community organization are vital aspects of fostering meaningful, sustained dialogue. As noted by Dr. Neil Jacobs, UFS Chief Science Advisor, and others, community dialogue and interdisciplinary integration have the capacity to foster a positive feedback loop. Optimizing communication pathways and organizational clarity can support a knowledge transfer between those entering the UFS through workshops, training, and other capacity-building platforms designed by EPIC and members of an institution at large. Creating space for discussions surrounding research challenges and successes has the capability to spark innovation across existing and future stakeholders.

Responses from the post-workshop survey also yielded feedback on one's degree of connection to the UFS as well as the organization's level of collaboration. In terms of community dialogue, producing more tools to communicate and work alongside partners in the academic and government sectors would help to foster a more cohesive, co-producing environment. Moreover, participants expressed significant interest in facilitating greater dialogue between students and researchers of varying disciplines. Currently, a large portion of interest roots in the field of atmospheric science. However, in order to build a fully-coupled Earth System Model, attendees highlighted the need to engage with members of the computer science, data science, and oceanographic communities, amongst other disciplines. Supporting community dialogue with members of these disciplines can help expand research interests and focus areas under the UFS.

Governance

The UIFCW facilitated various discussions on governance as well as yielded a multiplicity of suggestions for a path forward. To begin analyzing stakeholder feedback

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in this area, understanding community engagement best practices for governance and decision-making is essential. Social science research conducted prior to the workshop highlighted key tenets behind a meaningful community structure. Designing an accessible governance structure where consent from all stakeholders and interested parties is both accounted for and internalized is one facet of a decision-making platform (Colvin et al., 2016, pp. 484-490). Additionally, it is clear the distinction between a peer-based power structure and a hierarchical power structure generates vastly different forms of community engagement experiences. While the latter distinguishes between experience levels and capacities, the former supports the integration of consistent input and perspectives (Yet et al., 2022, pp. 190-207). As a result of consent and interdisciplinary forms of thought, trust and cohesion are rooted in the discussions between stakeholders. This in turn generates a fruitful form of deliberation (Colvin et al., 2016, p. 486).

Furthermore, governance structures are supplemented by the integration of community values and context. For example, tailoring solutions and project timelines based on a partner's context aids in creating trust and goal alignment (Kaur et al., 2020, p. 13; Dyer et al., 2014, p. 140). Considering a stakeholder's experience level and ideas for a particular project is foundational in yielding cooperation, capacity-building, and knowledge transfer. These elements relate to the aforementioned discussion of co-production as they similarly seek to foster broad innovation and community dialogue by way of designing an organized yet accessible governance structure.

At the UIFCW, stakeholders expressed interest in the formation of a Community Modeling Board (CMB) to enhance community communication, collaboration, and coordination on the UFS within the broader Earth system modeling community across sectors to serve as a point of contact for leveraging community expertise to advance the UFS and to provide strategic advice to the UFS Steering Committee (UFS-SC) on the UFS. Specifically, attendees questioned the roles of contributors and leadership in decision-making as well as model integration in the research-to-operations funnel of the UFS. Attendees also questioned who would delegate the leadership of CMB and how it may compare to current forms of governance under the UFS and EPIC. It was shown that clarifying organizational unity for entry would help confirm the role CMB would have in making decisions surrounding one's work and contribution to the UFS. Within these discussions, various questions were raised that focus on the major concerns and perspectives of attendees:

1. Who makes the decisions for how model components are added to the UFS?
2. Who has accountability, and how does this weigh with autonomy?

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3. How many leadership and organizational boards are necessary?
4. What gaps will be addressed by the CMB, and how does this relate to the UFS Steering Committee?

Multiple characteristics were questioned by attendees as they relate to the structure of how governance should be designed and allocated. These keywords include transparency, unity, accountability, objectivity, and autonomy. Satisfying each of these elements through a flexible governance structure is no small feat. Rather, future discussions on the CMB should carefully consider the role of each of the aforementioned tenets in sustaining engagement, organizing model development, and supporting vast stakeholder use and applications. Attendees expressed interest in seeing greater access to code, funding outlets, and inclusivity across the public, private, and academic sectors as foundational characteristics of a future governance system. Moreover, participants considered how perspectives will be balanced as a fully-coupled Earth System Model is formed and how contributing voices will be accounted for in discussion and consensus. The topic of capacity-building appeared to be a major element in determining one's ability to co-contribute to decision-making and strategy-building under the UFS.

As the dialogue between panelists and attendees progressed, essential feedback was collected. Suggestions such as liaisons between partners, advocacy and incentives for participation, and reducing bias were common threads of discussion between stakeholders from the public, private, and academic communities. It is recognizable that ensuring diverse participation as well as the willingness to act on suggestions for a CMB will yield greater engagement and cohesion in the future.

[1]See glossary of terms for definition

IDEAS FOR A PATH FORWARD

In an effort to develop ideas for a path forward in the realms of EPIC and the UFS, this section will follow this thought process: a discussion of community ideas, the formulation of action items, and a brainstorm on pathways to consider for the future of EPIC and UFS. As a product of the three aforementioned components, evaluating the evolution of UFS and EPIC frameworks, co-production, a community environment, governance structures, and capacity-building is possible.

Community Ideas

It was generally agreed among stakeholders from the private, public, and academic sectors that creating and delegating liaisons for enhanced communication and integration would improve the UFS community. Specifically, attendees expressed how it can be a challenge to converse and share knowledge with other participants of the UFS. In respect to model development, integration decisions, and growing the interdisciplinary focus of EPIC and the UFS' missions, creating liaisons, across working groups and application teams for example, to bridge and translate interests and challenges could aid in forming meaningful partnerships.

A second community idea was for the UFS and EPIC to actively incorporate diverse disciplines and contributors from the model development arena to the various UFS applications. Given the goal to create a fully-coupled Earth System Model, ensuring the representation and participation of disciplines and experiences beyond atmospheric science could help to expand the improvements and use of these modeling systems. Additionally, attendees suggested the need to clarify the structure and decision-making process under a governance structure as it relates to internalizing and acting on diverse community feedback and expertise.

Stakeholders and panelists noted the need to develop incentives that entice participation and sustained, meaningful engagement. Beginning with the undergraduate level, promoting the UFS as a platform to advance modeling capabilities and weather prediction performance is essential to encourage diverse participation. Whether these incentives take the form of funding, training sessions, mentorships, fellowships and internships, or workshops, encouraging and building a connection to the younger generation will significantly aid in UFS' mission to build a fully-coupled Earth System Model. The aforementioned incentives also encourage the expansion of funding and collaboration platforms where students, early-and mid-career members can converse and problem-solve collectively. Furthermore, participants of the post-workshop survey noted their interest in expanding the UFS' applicability and

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inclusion of non-technical users, managing project timelines, and expanding HPC access for varying levels of experiments. Acting on these suggestions may yield greater, more sustained participation from community members with differing levels of coding experience.

Lastly, supplementing the discussion on incentives was the brainstorming around capacity-building. Workshop attendees noted the importance of supporting cloud computing for students. Enhancing both the access and project creation with cloud computing can play a large role in facilitating innovation at institutions with limited resources. As such, stakeholders appreciated the plan to introduce additional fellowships and internships through EPIC to connect students with weather modeling endeavors.

Action Items

During the final session of the UIFCW, attendees, the Office of Science and Technology Integration (OSTI)-Modeling Program Office leadership, UFS leadership, and EPIC leadership generated various action items. These suggestions denote near-to-confirmed pathways and projects soon to be developed by EPIC and UFS leadership in an effort to improve community engagement, capacity-building, and decision-making capabilities.

➔ ***Action Item #1: Outreach***

Due to barriers in communication as relayed by stakeholders, improving the UFS and EPIC's outreach efforts to existing and potential participants in UFS' modeling community is essential. After internalizing stakeholder feedback, UFS and EPIC leadership seeks to develop outreach for cross-sector partnerships. This effort can take the form of building an online forum to foster communication across developers and users as well as expanding the use of social media platforms. Additionally, developing outreach may focus on promoting the UFS at the college-level, and interacting with undergraduate and graduate students to better understand code education and project development.

➔ ***Action Item #2: Communication***

Stakeholder concerns regarding communication also focused on user support, project assistance, and opportunity elements of the UFS and EPIC. Stakeholders requested the creation of a mailing list to current and potential users that would supply information on new funding opportunities, training sessions, user assistance, and educational experiences such as fellowships and internships. It is also important to

[1]See glossary of terms for definition

note that communication needs to be better coordinated between the UFS community and EPIC.

➔ ***Action Item #3: Governance and Integration***

There is a need to clarify and confirm governance structures as they relate to a Community Modeling Board, the UFS Steering Committee, and EPIC. Stakeholder feedback for the future of the UFS includes the need to build an interdisciplinary, inclusive, and accountable governance system. Delegating representatives for a future modeling board requires careful consideration of transparency, objectivity, and autonomy. As such, leadership noted their commitment to clarifying the roles of the Community Modeling Board as it relates to the aforementioned elements discussed at the UIFCW.

➔ ***Action Item #4: Capacity-Building***

A final action item generated by leadership at the UIFCW was the development of capacity-building opportunities. Specifically, EPIC stated its upcoming release of student opportunities including fellowships and internships. Supplying community support in the forms of training and funding were widely recognized as essential tenets of a modeling community under the UFS. As a result of this consensus, the leadership of the UFS and EPIC released their plans on expanding these opportunities for the near future.

Brainstorm: Pathways for Exploration in the Future

As a final element in the discussion of ideas for a path forward, I will present potential pathways UFS and EPIC can explore that seek to address stakeholder feedback and suggestions. These ideas take the form of the following five sections: UFS and EPIC, co-production, community environment, governance, and capacity-building.

UFS and EPIC

In order to build and maintain a cohesive, collaborative modeling community, addressing the ambiguity surrounding the roles and responsibilities of EPIC, UFS, and UFS R2O is vital. The missions as well as the governance structures in the aforementioned entities are necessary in sustaining community engagement and participation. To reiterate, the UFS is a modeling system and community, UFS R2O is a NOAA-funded project formed to develop the next generation of operational forecast models from the UFS, and EPIC is a NOAA-funded program to support the community to engage with the UFS. As such, developing charters and points of contact for each

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respective body would help appropriately delegate roles and help each entity work in cohesion.

Aligning missions and charters with the governance structures of each entity will help to optimize the collaborative nature of community modeling; unifying rather than isolating partners and projects. These efforts can be done while confirming the roles of a future Community Modeling Board and the UFS Steering Committee.

Co-Production

Fostering co-production[1] across partners is another pivotal element for improving community engagement elements in the UFS. Specifically, expanding investments in funding and training exercises that begin at the university level could amplify accessibility and the incentive to work with the UFS. Creating an environment where students can gain access to code and mentorships at early-college or early-career stages will lessen barriers to entry and help spark knowledge transfer.

Additionally, co-production should serve as another active element in events like workshops and discussion forums. Facilitating conversations around research goals, challenges, and successes are all integral facets of building an environment where collaboration is encouraged.

Community Environment

Building on community modeling as a function of environment and collaboration is another key area of improvement for the UFS. A suggestion for expanding the integration of diverse disciplines and stakeholders is to design an open communication platform. Given the existing open-source code nature of the UFS, facilitating knowledge transfer and problem-solving through group efforts may encourage greater cross-sector partnerships.

As identified in the conversations at the UIFCW, discussions surrounding the technical components of model development outweigh those of knowledge transfer. Creating a culture through resources like online forums may help to spark interest in group dialogue surrounding future project ideas, challenges, goals, successes stories, and prospects. In turn, more relationships built on innovation can be formed as a community of practice seeking a co-producing and encouraging environment.

Governance

Supplementing the conversation above surrounding governance structures including those of EPIC and UFS, designing a platform based on capacity-building can channel diverse perspectives and direct projects in a collaborative manner. Below is a

[1]See glossary of terms for definition

generation of potential teams where resources, communication, and engagement can be amplified through a general governance system.

➔ ***"Entry Team"***

The creation and delegation of an "Entry Team" would tailor resources and project timelines according to the stakeholder. By doing so, this team would lessen entry barriers and project workflow interruptions. Resources can include training, mentorships, FAQs, a mailing list, and direct points of contact for case-by-case project concerns. Additionally, tailoring entry scenarios based on a stakeholder's context and goals can help facilitate meaningful engagement early.

➔ ***"Support Team"***

The role of a "Support Team" would aim to funnel investment, provide training, and facilitate active dialogue across partners. Similar to the "Entry Team," this entity would tailor training resources and points of contact depending on the context of a stakeholder, including their coding experiences, project timelines, and funding capacity. Moreover, this team would help promote and direct opportunities such as training courses, workshops, internships, and user guide support sessions. Lastly, the dialogue component of this group would be to design and monitor chat systems such as Slack, online question and answer forums (e.g., GitHub), and other potential platforms. Here, team members can support participants as they work through projects, manage platforms for cross-sector communication, and funnel potential concerns to leadership.

➔ ***"Application Team"***

An "Application Team(s) would play a pivotal role in guiding developers, users, and other participants through the R2O2R (research-to-operations-to-research) funnel (Fig. 5). This team(s) would assess the readiness-level of participant projects, navigating researchers and developers through points of entry and re-entry in the R2O2R pathway of the UFS. Additionally, the application team(s)would supplement feedback on projects and concerns. Facilitating conversations around knowledge transfer and cross-sector suggestions will serve as a major responsibility of the "Application Team." In this way, the team can manage requests and suggestions from developers, users, and forecasters, framing project timelines and goals.

[1]See glossary of terms for definition

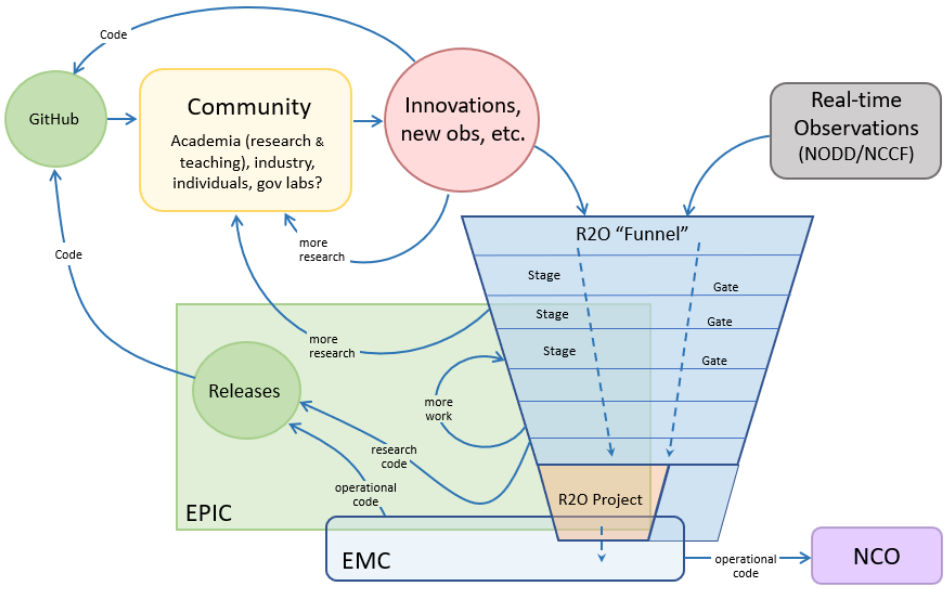

Figure 5: Proposed Research to Operations to Research (R2O2R) Funnel.

➔ ***"Engagement Team"***

The final, potential team under a governance structure for the UFS is the "Engagement Team." This group would be responsible for sparking interests and developing participation incentives for students and other stakeholders at various educational, academic and career stages. Specifically, this team would manage social media platforms, promoting opportunities such as internships, fellowships, and research success or progress and problem-solving stories. Developing social media platforms as outreach avenues can help to address the participation gaps recognized at the workshop. Additionally, the "Engagement Team" would help design workshops based on context: events that focus on undergraduate to graduate-level research, training exercises, and innovation goals. Lastly, this team can be a hub for mentors that serve as navigators and supporters for all entry-levels, facilitating conversations, providing training, and directing questions and concerns to the appropriate team.

Capacity-Building

A final suggestion for EPIC and UFS is to amplify capacity-building. The comments above largely contribute to the considerations in this section. As such, acting on forms of the suggestions relayed by stakeholders can help to expand and sustain capacity-building as it relates to building a community under the UFS. Specifically, at the workshop, stakeholders noted their interest in the expansion of training sessions, user guides, and active support systems to manage challenges with

[1]See glossary of terms for definition

accessing code. Additionally, responses from the post-workshop suggest managing and offering UFS-focused testbeds from EPIC would help to expand research and participation roles under the UFS. Considering stakeholders' integration pathways while aligning these elements with the missions of UFS and EPIC as a "for the community, by the community" would help contextualize capacity-building further.

[1]See glossary of terms for definition

CONCLUSIONS

The rising challenges posed by extreme weather events and climate change progression call for the advancement of weather forecasting and prediction. Addressing these crises is possible through cross-sector partnerships. As seen by the discussions and development of goals at the UIFCW hosted by the EPIC, the UFS, and the UFS R2O in College Park, Maryland and online, creating and curating a UFS modeling community committed to advancing innovation is essential.

The UIFCW highlighted the importance of stakeholder feedback and integration as integral facets of aligning user, developer, and operational needs to EPIC and the UFS. Analysis of social science research, workshop presentations, question and answer sessions, and a post-workshop survey led to community engagement best practices as they relate to building and improving a modeling community under the UFS.

Analyzing the presence, absence, and need for improvement of the following community engagement best practices was a key facet in the analysis: co-production, community values and dialogue, governance, and community environment. In their current form, the UFS and EPIC channel elements of these practices, and their success is the motivation recognized among stakeholders to foster cross-sector innovation. Members of the academic and private sectors as well as government partners appear committed to fostering community-building and the continuation of open-access collaboration. Furthermore, the UFS and EPIC's use of open-source code is a significant benefit among those wishing to participate in the UFS. However, with these advantages come various challenges faced by users and developers. These challenges include limited user support, coding barriers, low level of collaborator interaction, compute resource barriers, and eligibility concerns. As such, the modeling framework code releases of the UFS are impeded by structural limitations posed by workflow and documentation limitations as well as the lack of diverse presence at events like the UIFCW.

Considering a path forward for EPIC and UFS and their motivations to build and sustain a cohesive modeling community call for improvements on two fronts: infrastructure and engagement. The former can include focusing on the allocation of funding resources, support systems, training, designing communication platforms for stakeholders ranging from code developers to researchers to forecasters, and clarifying a governance structure. The latter constitutes an expansion of co-production elements including aligning project goals and timelines with context, creating incentives for diverse participation, and incorporating a diverse range of disciplines in the community

[1]See glossary of terms for definition

of UFS, fostering capacity-building and knowledge transfer.

The UFS and EPIC's missions to foster a community structure have the capacity to advance operational weather forecasting and prediction. Internalizing and acting on stakeholder feedback and the suggestions outlined above will play a significant role in mobilizing action items in an effort to enable impactful societal outcomes.

[1]See glossary of terms for definition

[1]GLOSSARY

The following list of terms are provided with definitions based on the context of this report, the Unifying Innovations in Forecasting Capabilities Workshop, and the UFS.

Co-production: the ongoing collaboration between sectors through actions like knowledge integration, partnerships, community problem-solving, and goal development.
EPIC: Earth Prediction Innovation Center
Government: membership to government entities including and not limited to NOAA and other federal agencies
JEDI: Joint Effort for Data assimilation Integration
NOAA: National Oceanic and Atmospheric Administration
OSTI: Office of Science and Technology Integration
Q&A: Question and Answer
R2O: Research to Operations
Sector: entity membership including and not limited to private, public, and academic affiliation
Stakeholder: UIFCW attendees and UFS membership affiliation representing private, public, and academic sectors and community members
UFS: Unified Forecast System
UIFCW: Unifying Innovations in Forecasting Capabilities Workshop
Weather Enterprise: The Weather, Water, and Climate Enterprise, also known as the Weather Enterprise for short, comprises three main sectors that contribute to the science of weather and weather forecasting -- academia, government, and America's Weather Industry.

[1]See glossary of terms for definition

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[1]See glossary of terms for definition

APPENDIX 1

Post-Workshop Survey, Open-Ended Questions

For current users of the UFS.

1. As a user, what role do you envision for yourself in the ongoing development of UFS (e.g. offering ideas, reporting bugs, contributing code or documentation)?

2. How would you describe your experience working with the UFS, such as interaction with other users, usability, and support resources?

3. When thinking about participating in the development of UFS, what are some additional resources (e.g. tutorials, training) or existing barriers (e.g. documentation, responsiveness of support) that we need to consider to promote greater collaboration among users?

4. What would incentivize you to participate in the UFS?

[1]See glossary of terms for definition